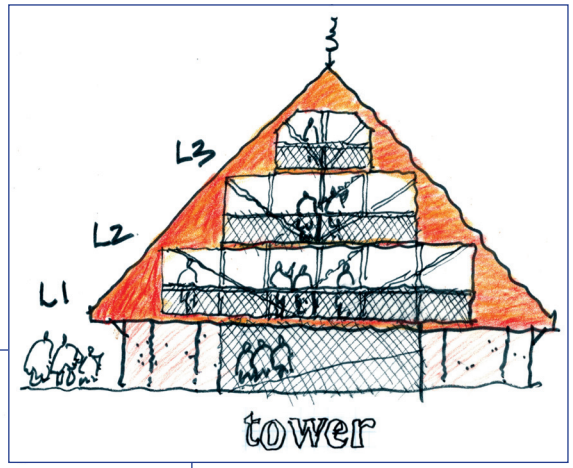
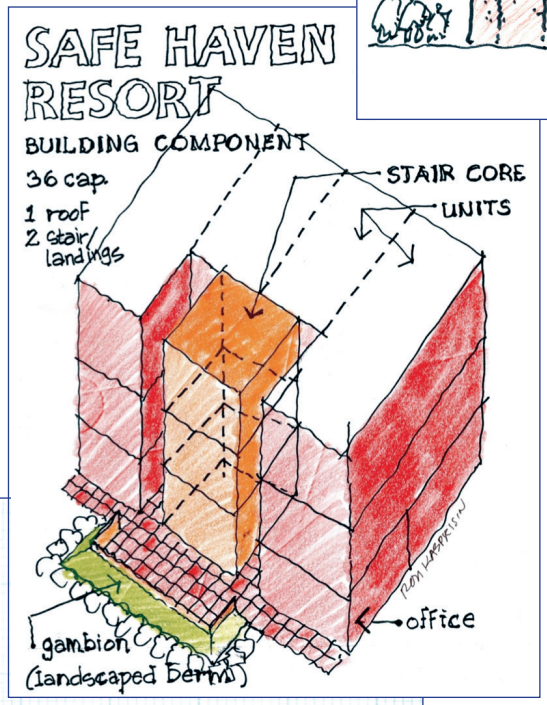
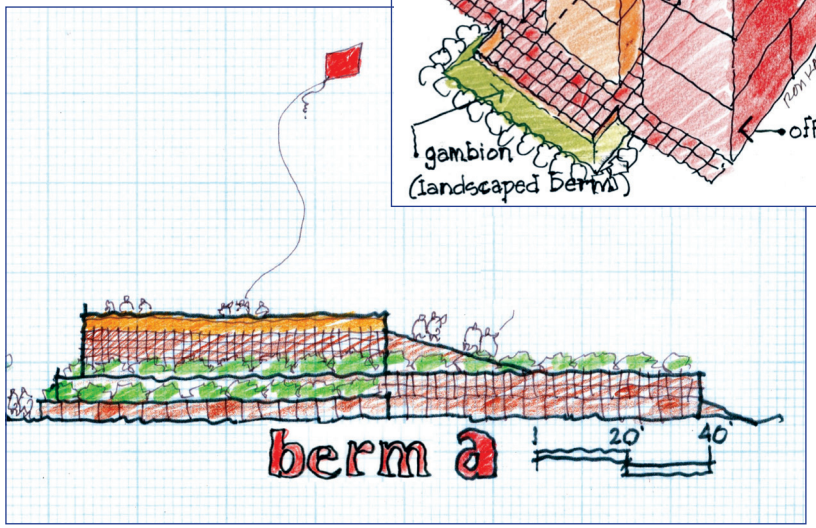
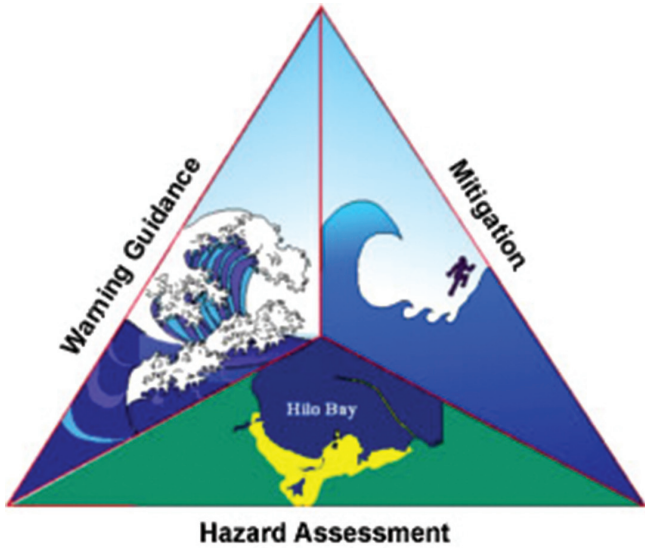
Project Safe Haven:

Vertical Evacuation Structures Conceptual Cost Analysis









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Introduction

The Project Safe Haven Cost Estimating Team developed detailed cost estimates for four representative vertical evacuation structures, which are described in this report.

Because of the varying site differences, facility height and design it is difficult to offer accurate total costs for all safe haven facilities proposed during this process. However, having said this, general estimates can still be made.

The residents of Pacific County suggested 20 facilities offering tsunami safe havens for 6,300 residents through the construction of 13 berms, 5 towers and 2 buildings (see Table 1). If construction costs for all facilities are representative of those per person capacity estimates that have been developed, the total cost for the 20 safe haven facilities could be in the neighborhood of $13 million (see Appendix A).

The residents of Grays Harbor County have suggested 32 facilities offering tsunami safe havens for 18,450 residents through the construction of 3 berms, 18 towers, 8 tower/berm combination and 3 buildings (see Table 2). The total cost for the 32 safe haven facilities could be in the neighborhood of $64 million (see Appendix B).

Detailed within this report are detailed construction cost estimates for four select vertical evacuation structures designed for Project Safe Haven: Pacific County and Project Safe Haven: Grays Harbor County. The purpose of the estimates was to start developing further information for the economic feasibility of constructing tsunami safe haven structures for various local communities along the Washington State coast. These structures would have to withstand the forces of a magnitude 9.1 Cascadia Subduction Zone earthquake and the resulting tsunami inundation. Four different structures sited in different locations were estimated: two separate earthwork berm designs, a tower in a market area, and a fire station. These structures not only will act as a refuge during the tsunami event but will also be active facilities that serve their communities on a daily basis.

The first tsunami refuge would be an earthwork berm to be located at the Long Beach Elementary School site at Washington Avenue & 5th Street South. The berm would be located next to accompanying athletic fields and playgrounds, and provide an opportunity for large-capacity berm space integrated with school facilities. The site's existing open space can accommodate a berm structure that could serve as a play area, seating area for recreation events, kite-flying mounds, and viewing area that is accessible from a sloped earth ramp. The cost estimated for this structure came to a total of $839,708 with the majority of the costs involving earthwork and concrete placement.

The second tsunami refuge would be the Tokeland Farmers Market Tower. It would be a basic tower with two platforms that could also serve the community as a covered market area. The top platform would be the tsunami refuge floor and would become accessible by a ramp on the backside of the building. The estimated cost for this structure is $385,319 with the majority of the costs involved in the foundation, structural system and the access ramp.

The third tsunami refuge would be the Grayland Fire Station located at the vicinity of McDermott Lane in the city of Grayland. The fire station would include a two-story portion for offices and firefighter facilities, as well as four 16 feet x 40 feet bays to accommodate emergency vehicles. The

tsunami refuge area would be achieved by using its roof section, made accessible by a ramp at the side of the building structure. This building would sit on a foundation of battered piles. The estimated cost for this building is $1,384,013 with the majority of the costs attributed to the pile foundation and robust structural system.

The fourth safe haven would be the Spinnaker Park berm structure located at Spinnaker Street and Storm King Avenue in Ocean Shores. It would be a berm with reinforced concrete walls providing a barrier from tsunami inundation. This berm would be part of a park facility to serve as play areas, seating areas for neighborhood events, kite flying mounds, viewing areas, children's forts, and dog walking areas. The berm has a stepped platform structure located at the base of the safe zone, and would be a debris deflection barrier. The berm would also have two hardened access ramp-slopes protected from both ocean and bay inundation sources. The estimated cost for the berm with reinforced concrete walls is $1,163,272. An option of providing a berm structure using sheet piling instead of reinforced concrete walls was analyzed but it was not economically viable when compared to the concrete wall option.

Table 1: Pacific County estimates
Map numbers correspond to map in Pacific Safe Haven: Pacific County *report*

Pacific County Site Estimates			
Map Number	Community	Type	Cost
B1	Long Beach	Berm	$659,297
B2	Long Beach	Berm	$722,208
B3	Long Beach	Berm	$529,345
B4	Long Beach	Berm	$577,233
B5	Long Beach	Berm	$476,366
B6	Ocean Park	Berm	$527,344
B7	Ocean Park	Berm	$388,286
B8	Ocean Park	Berm	$507,381
B9	Ocean Park	Berm	$769,830
B10	Ocean Park	Berm	$423,765
B11	Ocean Park	Berm	$822,725
B12	Ilwaco	Berm	$529,345
B13	Ilwaco	Berm	$599,130
PK1	Tokeland	Building	$1,772,685
PK2	Tokeland	Building	$646,997
T1	Tokeland	Tower	$358,023
T2	Tokeland	Tower	$425,619
T3	Tokeland	Tower	$323,501
T4	Tokeland	Tower	$359,187
T5	Tokeland	Tower	$360,351
			$11,778,618

Table 2: Grays Harbor estimates
Map numbers correspond to map in Pacific Safe Haven: Grays Harbor County *report*

Grays Harbor Site Estimates			
Map Number	Community	Type	Cost
1	Ocean Shores	Tower	$782,212
2	Ocean Shores	Tower	$1,246,299
4	Ocean Shores	Berm	$775,747
3	Ocean Shores	Tower	$3,339,039
5	Ocean Shores	Tower/Berm	$1,163,273
6	Ocean Shores	Tower	$836,607
7	Ocean Shores	Tower/Berm	$1,163,273
8	Ocean Shores	Tower	$856,037
9	Ocean Shores	Tower/Berm	$1,163,273
10	Ocean Shores	Tower	$836,607
11	Ocean Shores	Tower	$847,710
12	Ocean Shores	Tower	$1,228,372
13	Ocean Shores	Tower	$847,710
14	Ocean Shores	Tower/Berm	$1,163,273
15	Ocean Shores	Tower/Berm	$1,163,273
16	Ocean Shores	Tower	$836,607
17	Ocean Shores	Tower	$836,607
18	Ocean Shores	Tower/Berm	$1,163,273
19	Ocean Shores	Tower/Berm	$1,163,273
20	Ocean Shores	Tower	$836,607
1	Westport	Building	$2,815,371
2	Westport	Building	$1,903,606
4	Westport	Tower	$1,776,117
3	Westport	Tower	$1,762,672
5	Westport	Berm	$1,356,321
6	Westport	Tower	$1,762,672
7	Grayland	Tower	$1,311,608
8	Grayland	Tower	$1,325,054
9	Grayland	Building	$1,384,013
1	Taholah	Tower/Berm	$1,163,273
2	Taholah	Berm	$645,834
3	Taholah	Tower	$654,942
			$40,110,554

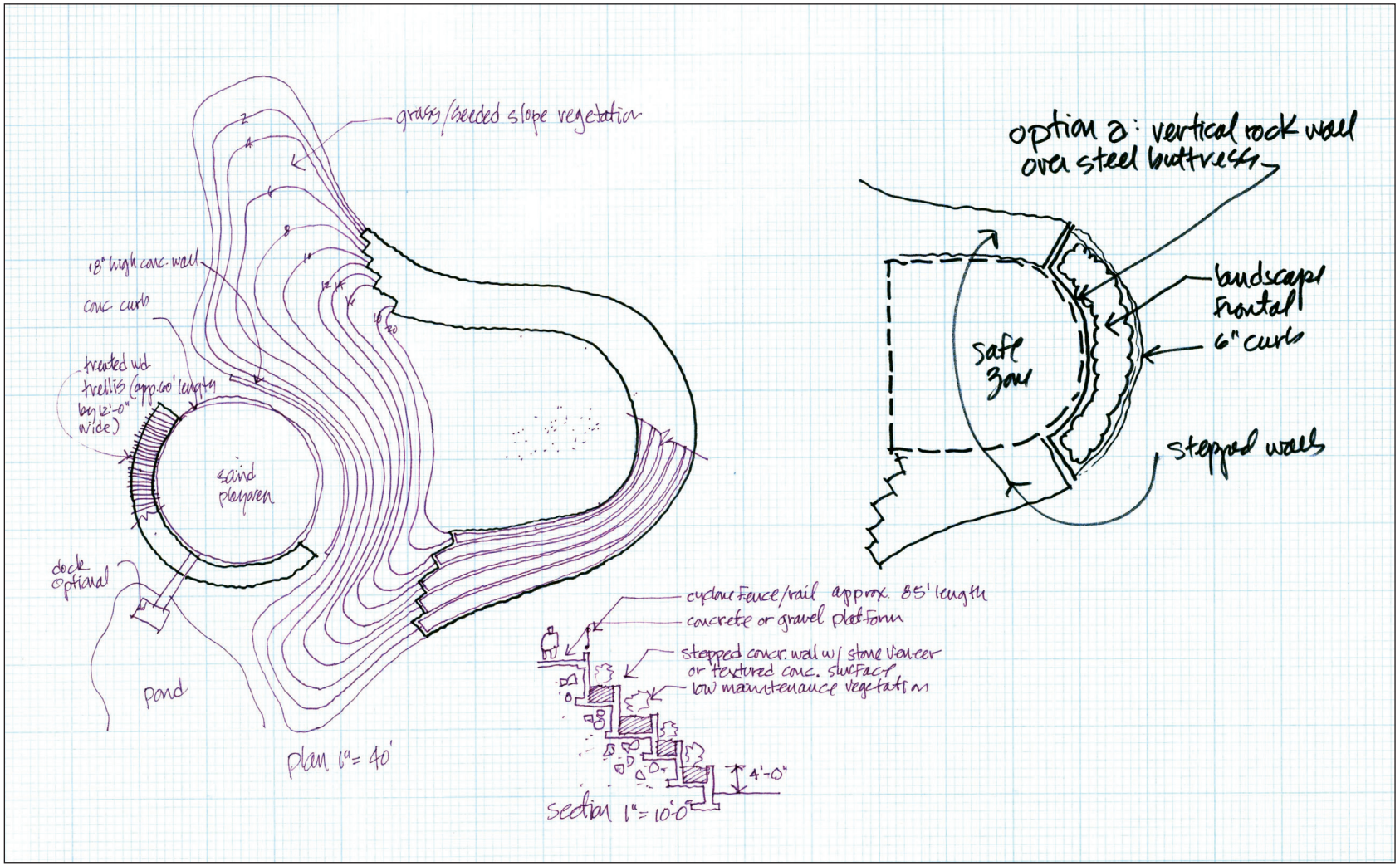

Figure 1: Elementary School site berm

Long Beach

Elementary School Site Vicinity, Washington Avenue & 5th Street South

- Elevation: 10 feet
- Capacity: 800 people
- Safe zone area: 8,000 square feet minimum

Berm Design Concept

The elementary school site represents a precedent location because school facilities and accompanying athletic fields and playgrounds provide an opportunity for large capacity berm structures integrated with school facilities. The school open space can accommodate berm structures that serve as play areas, seating areas for recreational events, kite-flying mounds, viewing areas, children's forts, etc. The structure is integrated with a peninsula-wide park and trail network, Discovery Trail, athletic fields and a small pond into a unique landscape feature for public use. In berm typology, (see Figure 1), a segmented berm provides two safe zone elevations with access ramp-slopes; surrounding a play area with sand base and small stage area; and seating for athletic facilities. In the berm is a single structure with larger safe zone area connected to the Pacific County Parks and Trails Network portage trails system.

Berm Estimate Assumptions

The estimate of this structure was completed using *RSMeans, Building Construction Cost Data, Assemblies Cost Data and Square Foot Costs for 2011*, in addition to quotes from a local contractor for piling, concrete and aggregate costs (see Appendix C).

Utilities

Site utilities include storm drainage with area drains, domestic water for irrigation and electrical service for light fixtures. Clear and grubbing of the property were included in the price but not rough grade.

Structural System

The berm structure will need to have the soil stabilized to prevent liquefaction during a seismic event and protect the platform area from tsunami inundation. In order to stabilize the soil a fabric will be placed in-between layers of 18" lifts. Once each 4'-high retaining wall is built, the fill will be placed to top of wall elevation with the fabric wrapping around the edges of the lift to further stabilize the fill. The material used for the backfill will be 1½" minus aggregate. Fine aggregate is possible for the fill materials but the cost difference would be negligible unless a closer quarry is found. All native soil that is removed from the area includes a 25% swelling factor and imported aggregate includes an 8% shrinkage factor when compacted. Transportation of the soil to and from the site includes an hour haul time.

To prevent scour at the base of the berm, the lowest concrete wall will extend 6' below grade. Constructing this wall will require excavation to construct a continuous footing at the base of the wall. Dewatering was not included in the estimate.

The stepped concrete walls were estimated as if they were landscaping retaining walls and include split faced decorative blocks along the façade.

At the stepped walls the estimate accounts for landscaping and drainage piping along each wall. Waterproofing was not included but may be desired to prevent seepage. Irrigation is included but may not be necessary with the low maintenance vegetation planted. Hydro seed is budgeted for the entire site.

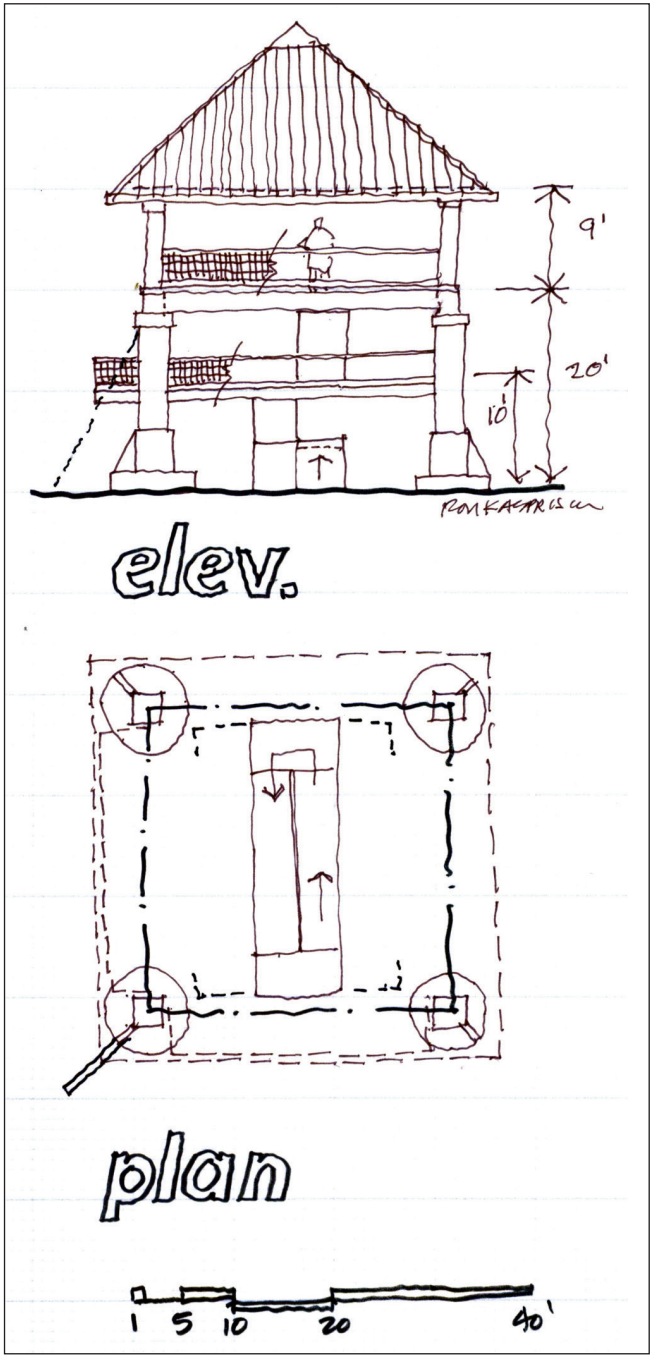

Figure 2: Tokeland Market Square tower

Tokeland

Marina Festival Viewing Tower

- Height: 20 feet
- Capacity: 80 people
- Safe zone area: 800 square feet minimum

Tokeland Marina Festival Viewing Tower

The Tokeland festival tower would be a tiered structure with an initial safe zone at 20 feet augmented by a smaller platform in the roof structure for non-physically challenged persons, accessed by a steel ladder with hand rails (see Figure 2). This platform would be considered a storage loft and not subject to ADA requirements. The main safe zone platform would be accessed by a ramp/landing structure to the rear of the tower and can be sacrificial, or breakaway. A roof structure is a part of the design to provide the additional safe zone tiered platform. The ground level would be open and available for information and sales booth activity during festival events.

Tower Estimate Assumptions

The estimate of this structure was completed using *RSMeans Building Construction Cost Data, Assemblies Cost Data and Square Foot Costs for 2011*, in addition to quotes from a local contractor for piling, concrete and aggregate costs (see Appendix C).

Utilities

The structure would have three site utilities serving the building: storm water, electrical, and fire sprinkler water. These would require three separate trenches with service assumed to be within 50 ft of the site. No site grading was included in this estimate. All native soil to be removed from the area includes a 25% swelling factor and imported aggregate includes an 8% shrinkage factor when compacted. Transportation of the soil to and from the site includes an hour haul time.

Structural System

The tower structure would consist of two levels of concrete framing supporting a wood roof structure. The four concrete columns would be supported on pile caps with three battered piles at each corner of the structure. This concrete structure would be designed to withstand the design seismic event and the top floor would be the location for the tsunami refuge.

Roofing

Above the refuge platform would be a wood structure with hip style roof. The roof structure would contain an attic space for additional people to congregate, but would only be accessible by ladder. The roof would be supported by four 12″ x 12″, 10′ high glulam columns. It would be a hip and ridge, metal-seamed roof.

Access

The access to all floors would be a 5′ wide galvanized steel ramp supported by 12 columns. An accordion-style steel ladder would be attached to the structure to provide access to the ground after the tsunami event. It was assumed that the ramp structure will be washed away and this ladder would serve as an escape for the people on the second platform.

Interiors

No interiors or coatings are included in this estimate except for the steel ramp, which is galvanized, and the wood members who have a premium of 15% included for pressure treated wood. Fire sprinkler protection has been included on all floors.

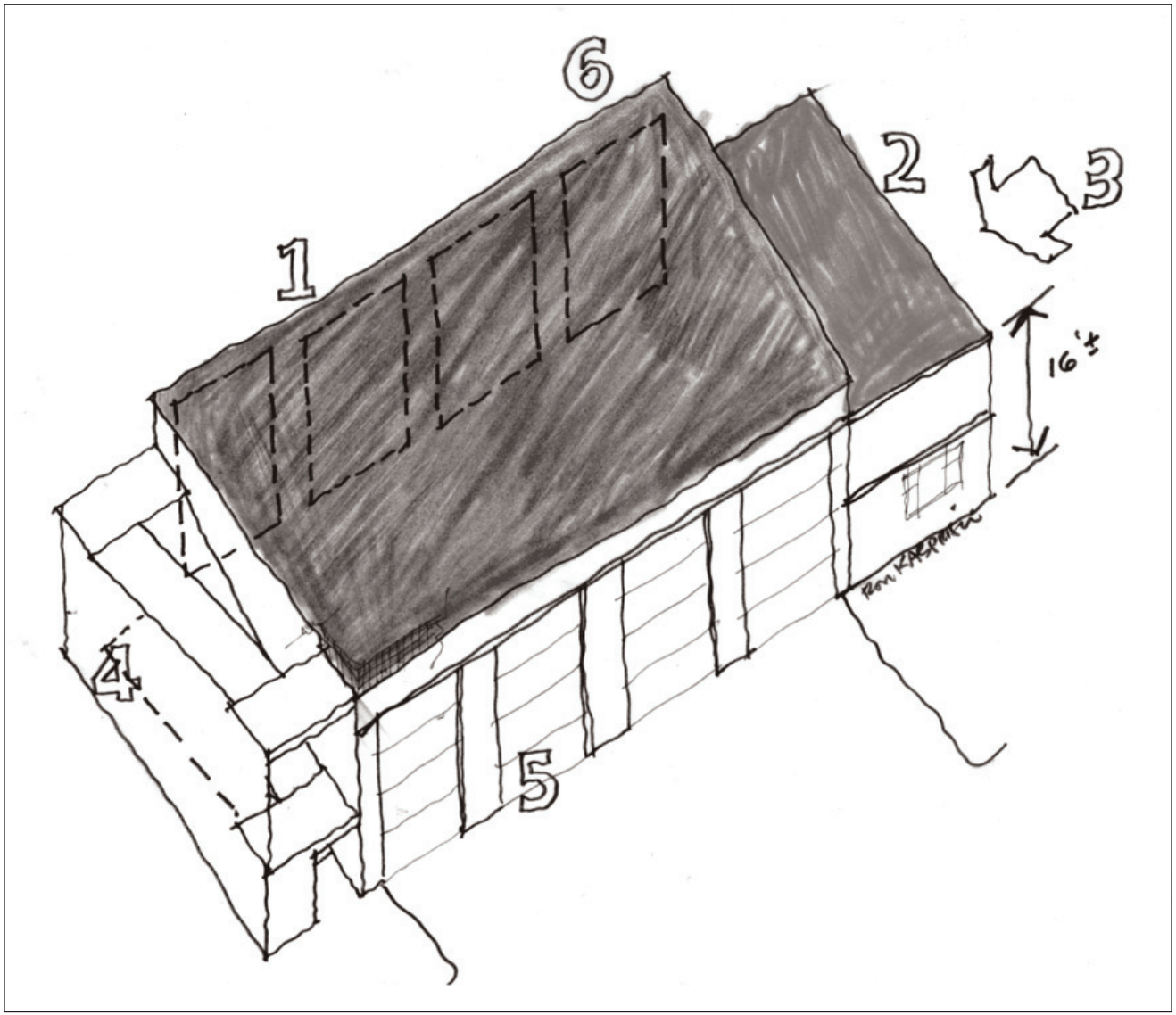

Figure 3: Grayland Fire Station concept

Grayland

Fire Station
McDermott Lane Vicinity

- Elevation: 10 feet
- Capacity: 300 People
- Safe Zone Area: 2,560 square feet minimum

Fire Station Design Concept

Fire station buildings can consist of a tsunami refuge component (one or more bays or loft area) or a fully hardened building structure with a flat roof safe zone. Access can be by ramps at the side of the building structure. A two-story component in part of the building can be used for offices, firefighter facilities, etc.

Fire Station Typology

Fire stations in smaller communities provide vertical evacuation structure opportunities and functioning community service/emergency facilities. Basic dimensions of fire stations for smaller communities are generally in the dimensions listed below, subject to site conditions and changing local and state standards:

- Bay size: 16′ x 40′ , essentially providing a four feet space around all sides of fire department vehicles
- Garage doors front and back at 12′ x 18′, incorporating breakaway (sacrificial) design to minimize tsunami loading on the building structure (see 5 & 6 in Figure 3)
- Building height approximately 20′ interior to 22′ overall
- Attached office and support service space

Safe Zones

- Vertical evacuation facilities can be accommodated by roof structures approximately 20′ to 22′ high; or, roof of office complex if inundation level and capacity are lower (see 1 & 2 in Figure 3)
- Pedestrian entry to roof from exterior ramp and interior stairs (see 4 in Figure 3)
- Safe zone can contain emergency supplies, ladders, and shelters
- Side walls of building are composed of unit materials such as split concrete block or panels specifically designed as breakaway walls (see 3 in Figure 3)

Fire Station Estimating Assumption

The estimate of this structure was completed using *RSMeans, Building Construction Cost Data, Assemblies Cost Data and Square Foot Costs for 2011*, in addition to quotes from a local contractor for piling, concrete and aggregate costs (see Appendix C).

The building would have 2,560 square feet of single story construction, taking up four bays with dimensions of 16′ x 40′ to house fire engines and other emergency vehicles. A single bay of 24′ x 40′ would contain the offices and support space section on the second floor. The tsunami refuge section would be the roof above the service vehicle bays.

Utilities

Site utilities are assumed to be 100 feet from the structure and including water, fire water, sewage, storm, electrical, and natural gas. Storm drainage includes piping along the exterior of the building. All native soil that is removed from the area includes a 25% swelling factor and imported aggregate includes an 8% shrinkage factor when compacted. Transportation of the soil to and from the site includes an hour haul time.

Structural System

The framing of the building would consist of a steel structure supported on a

foundation made up of battered pilings and pile caps. The engine sections of the building have been assumed to be 20′ high and the office section 16′ as shown in Figure 3.

The foundations would consist of battered piles 40 feet deep at 18 pile cap locations. The pile caps would be located at the corners of each bay and in the midsection, with two piles each for 6 locations and 3 piles at the corners and shear wall ends. The first floor would be a concrete slab on grade.

The frame of the building would be steel and the roof would be constructed to withstand the design seismic event and to support the resulting live load of evacuees. The support space above the office would be wood structure to reduce costs.

Exterior Walls

The exterior walls would be split-faced CMU surrounding the four bays containing the vehicles. This enclosure would also have 8 doors for vehicle access in the front and back. At the bay that contains the office, the first 8 vertical feet would be CMU walls and the top 8 feet would be wood siding. All of these walls would incorporate breakaway detailing concepts.

Doors

The interior and exterior doors have been estimated based on square foot costs for the office bay only, since the engine section shows 8 doors for the vehicles. The desired size for these garage doors are 12′ x 18′ but the closest door size listed in RSMeans was a 12′ x 12′, 24 gauge, sectional door. An assumption was made by using the square foot material cost for the 12′ x 12′ door and then using that rate to determine the cost of a 12′ x 18′ door. The installation cost of the door was determined to be $6 per square foot based on the price average cost to install a 12′ x 12′ and 20′ x 14′ garage door.

Roof Access

Access to the roof would be by an interior stair and galvanized steel exterior ramp at the side of the building opposite the office bay. A steel accordion style ladder has been included in the estimate for access off the roof if the stairs and ramp are washed away during the tsunami.

Interiors & MEP

The interiors of the building are estimated on a square foot assumption only since design has not been completed. Interior mechanical, electrical and plumbing systems are budgeted in the same fashion.

Landscaping

The amount included for landscaping is 3,000 square feet which was used to make a square foot calculation in that the outside improvements. Also included are concrete flatwork driveways for the vehicles leading into the bays. Clearing and grubbing of the property were included in the price but not rough grade.

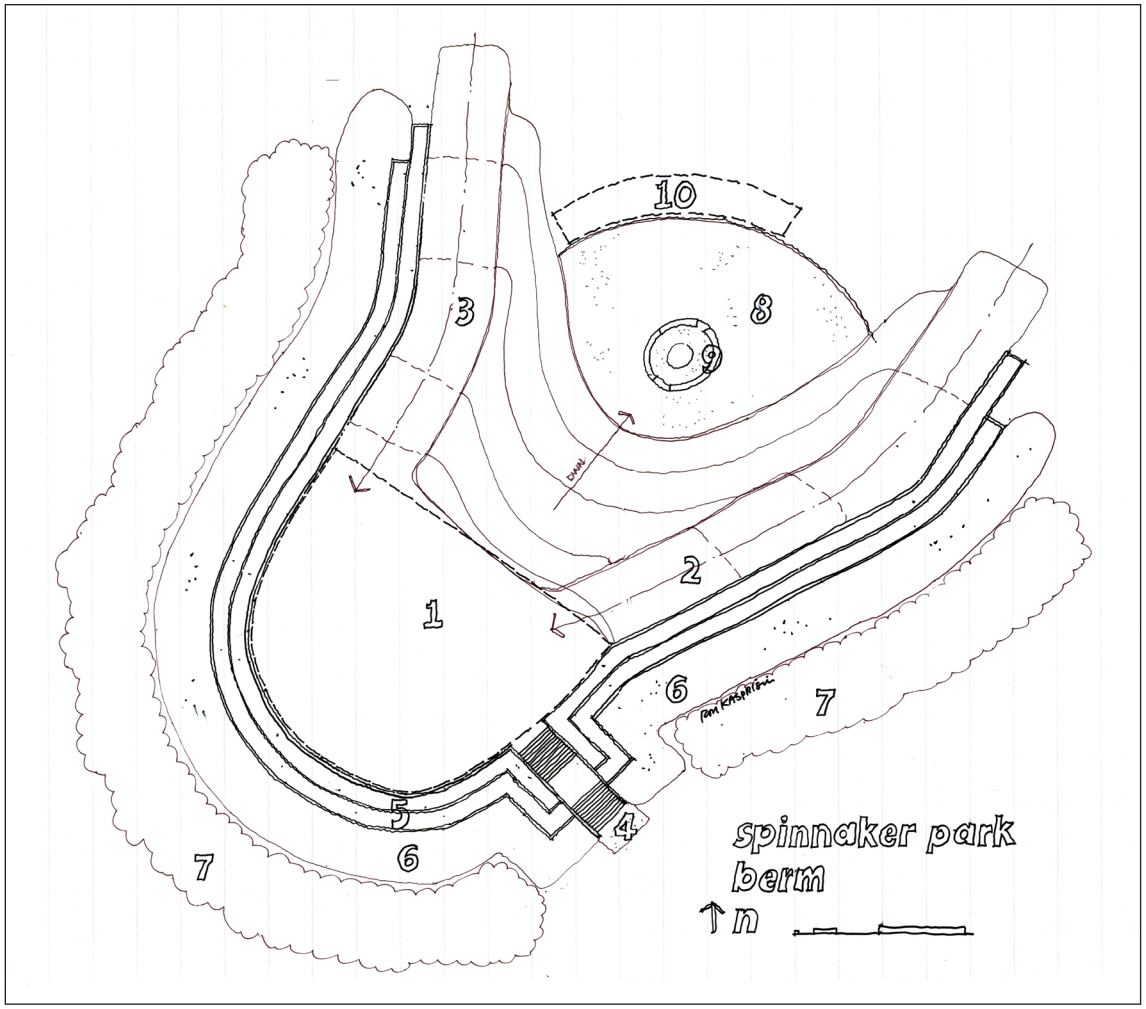

Figure 4: Spinnaker Park berm

Ocean Park

Spinnaker Park Berm

- Elevation: 17 feet
- Capacity: 500 people
- Safe Zone Area: 5,000 square feet minimum

Berm Only Design Concept

The Spinnaker Park site, aligned along Spinnaker Street in the south end of the Ocean Shores peninsula, represents a precedent location for neighborhood parks that can provide an opportunity for integrated large capacity berm structures.

The berm would be part of a park facility that serves as play areas, seating areas for neighborhood events, kite-flying mounds, viewing areas, children's forts, dog walking areas, etc. The structure would provide a tsunami refuge with two hardened access ramp-slopes protected from both ocean and bay wave actions. A two-stepped planting structure, sacrificial (breakaway) in the event of tsunami inundation, would be located at the base of the safe zone and serve as a neighborhood garden facility and debris deflection barrier. A play area and event space would be incorporated into the center of the berm with open play and dog-walking areas around the perimeter.

Berm Estimate Assumptions

The estimate of this structure was completed using *RSMeans, Building Construction Cost Data, Assemblies Cost Data and Square Foot Costs for 2011*, in addition to quotes from a local contractor for piling, concrete and aggregate costs (see Appendix C).

Utilities

This site would include concrete flatwork at the top and base of the berm, a 12′ x 60′ wood trellis and a flight of stairs that lead up to the top of the berm. Hydro seed is budgeted for the entire site. Site utilities would include storm drainage with area drains, fire and domestic water, and electrical service for light fixtures. Clearing and grubbing of the property were included in the price but not rough grade.

Structural System

Two types of walls at the top of the berm were included as options in this estimate. This wall would act as the main barrier from preventing the tsunami wave from washing away the berm.

The first option (see Figure 4) was a sheet pile wall driven 8.5′ deep into the ground and would stand 17′ above grade with the berm fill material behind this wall. An 8″ thick concrete wall would be cast in front of the sheet piling to cover the exposed steel sheet piling for aesthetic purposes, and can also act as an oxidation barrier due to the salt water and moist climate of the Washington Coast. The estimate includes a heavy sand blast to the concrete wall for aesthetic reasons.

The second option was building a 14″ thick concrete wall to retain the berm fill material. This wall would extend below grade for 6′ and above grade for 16′. This wall would serve in the same capacity as the previous sheet pile wall and would also have a heavy sand blast for aesthetic purposes. The embedded portion of this wall would require excavation to construct a continuous footing at the base of the wall. Dewatering was not included in this estimate.

The berm earthwork would be constructed with 1½″ minus aggregate compacted in lifts. Using a finer or lower-quality aggregate would not affect price unless it was brought in from a close source since the majority of all fill cost is due to a long haul from established quarries/batch plants. All native soil that is removed from the area includes a 25% swelling factor and imported aggregate includes an 8% shrinkage factor when compacted. Transportation of the soil to and from the site includes an hour haul time.

Landscaping

Below the sheet pile/concrete walls, two 4′ high landscaping retaining walls were included but resistance of these walls to tsunami inundation was not included since they are mainly aesthetic. They do include a heavy sand blast on the exterior faces and drainage piping along each wall. Waterproofing was not included but may be desired for all retaining walls to reduce seepage. Irrigation is included but may not be necessary with the low maintenance vegetation planted.

Conclusions

The residents of Pacific County have suggested 20 facilities offering tsunami safe havens for 6,300 residents through the construction of 13 berms, 5 towers and 2 buildings. A general cost estimate for the 20 safe haven facilities could be in the neighborhood of $13 million. The residents of Grays Harbor County have suggested 32 safe haven facilities for 18,450 residents through the construction of 3 berms, 18 towers, 8 tower/berm combination and 3 buildings. Total cost for these could be in the neighborhood of $64 million.

In this report, detailed estimates for four sites are given. For each site, certain challenges affect the estimated costs of the tsunami refuge structures. The challenges typical to each site are due to the remote location of the Washington Coast and more limited options in material supply and builder competition. Listed below are the individual cost estimates for the sites, as shown in Table 3.

Table 3: Estimate of project costs

Project Estimate Costs Summary	
Project/Site	**Cost**
Long Beach Berm	$839,708
Tokeland Farmers Market Tower	$385,319
Grayland Fire Station	$1,384,013
Spinnaker Park Berm RC Wall	$1,163,272

Table 4 shows total cost for the Long Beach Elementary School berm structure at $839,708 with the majority of the costs associated with the earthwork and concrete placement. While the costs to place earthwork materials in 18" lifts, wrapped in stabilization fabric, are significant, the haul distance to the site almost effectively triples the cost of fill materials. The remaining costs of the project are within an 8% range, higher or lower, of what is historically found on most construction projects based on RSMeans.

Table 4: Long Beach Elementary School berm estimate

Long Beach Berm	
Scope	**Cost**
Site Utilities	$49,814
Excavation-Backfill	$289,512
Concrete	$153,951
Landscaping	$74,094
Construction Totals	**$567,370**
Design Fees (8%)	$45,390
General Conditions (10%)	$56,737
Contractor Fees, O&P (15%)	$85,106
Construction Contingency (5%)	$28,369
Estimate/Design Contingency (10%)	$56,737
Project Total	**$839,708**

Table 5 outlines the estimated cost of the Tokeland Farmers Market Tower at $385,319 with the majority of the costs being associated with the foundation and structure. This is a result of the tower being built on battered piles and having a heavily reinforced concrete structure supporting the tsunami refuge platform. The

Table 5: Tokeland Farmers Market tower estimate

Tokeland Farmers Market Tower	
Scope	**Cost**
Site Utilities	$15,257
Excavation-Backfill	$13,034
Foundation	$66,757
Structure	$78,835
Roofing	$20,540
Stairs/Ramps/Guardrails	$55,734
Fire Protection	$10,195
Total	**$260,351**
Design Fees (8%)	$20,828
General Conditions (10%)	$26,035
Contractor Fees, O&P (15%)	$39,053
Construction Contingency (5%)	$13,018
Estimate/Design Contingency (10%)	$26,035
Project Total	**$385,319**

cost of having ramp access to the two platforms does account for a larger portion of the project costs but the lack of earthwork for this project does not affect the overall estimated price as it does on other projects listed in this report.

Table 6: Grayland Fire Station estimate

Grayland Fire Station	
Scope	**Cost**
Site Utilities	$36,509
Excavation-Backfill	$26,578
Foundation	$254,012
Structure	$188,273
Exterior Walls	$96,042
Roofing	$14,094
Stairs	$54,727
Interior Finishes	$36,786
Mechanical	$74,647
Electrical	$35,482
Plumbing	$44,934
Fire Protection	$19,155
Landscaping	$53,903
Total	**$935,144**
Design Fees (8%)	$74,811
General Conditions (10%)	$93,514
Contractor Fees, O&P (15%)	$140,272
Construction Contingency (5%)	$46,757
Estimate/Design Contingency (10%)	$93,514
Project Total	**$1,384,013**

Table 6 shows the cost associated with the Grayland Fire Station at $1,384,013 with the majority of costs associated with the foundation and structure of the building. In order for this structure to withstand the design seismic event and remain suitable for a vertical evacuation structure, it requires battered pile foundations and a robust structural system. Adding to the costs are the functionality requirements of an active fire station that includes features such as garage doors, extensive site work, and operation spaces for the tenants of the building. Since this project does not require a large amount of imported or exported fill materials, this project is not as affected by the earthwork cost as the other projects listed in this report.

Table 7 is the costs associated with the Spinnaker Park berm with reinforced concrete walls option, at $1,163,272. The earthwork contributes a significant amount of costs for the berm and the reinforced concrete wall and stepped landscaping also contribute.

Table 7: Spinnaker Park berm

Spinnaker Park Berm	
Scope	**Cost**
Site Utilities	$55,725
Excavation-Backfill	$385,762
Concrete Retaining Wall Surrounding Berm	$173,075
Landscaping Concrete	$100,323
Stairs/Ramps/Guardrail	$11,498
Landscaping	$59,612
Total	**$785,995**
Design Fees (8%)	$62,880
General Conditions (10%)	$78,599
Contractor Fees, O&P (15%)	$117,899
Construction Contingency (5%)	$39,300
Estimate/Design Contingency (10%)	$78,599
Project Total	**$1,163,272**

Bibliography and Additional Resources

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Appendices: Detailed Cost Estimates